Norman F. A. Brush

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MINES BRANCH

OTTAWA

MINERAL SCIENCES DIVISION

INTERNAL REPORT MS-65-110

AN ELECTRONIC ORE SORTER

by

R.H. Goodman, A.H. Bettens and C.A. Josling

(For publication in Canadian Electronics Engineering)

November 24, 1965

Mineral Sciences Division Internal Report MS-65-110

AN ELECTRONIC ORE SORTER

by

R.H. Goodman*, A.H. Bettens** and C.A. Josling**

- - - - - -

In a mining complex, there are three principal types of operations performed: the procuring and handling of materials, the sorting of valuable material from waste products, and the changing of the chemical form of the material. When an ore is mined, the barren rock has to be separated from the desired mineral; this operation is generally done by flotation, gravity, etc., after many crushing phases. A presorting of the ore is very desirable in that the waste material can be discarded before these milling and crushing procedures.

In the uranium mining industry, the presence of uranium ore is detected through its natural radioactivity but there are, as yet, very few techniques which allow the presence of non-radioactive elements to be determined. An electronic ore-sorting system using X-ray fluorescence has been developed at the Department of Mines and Technical Surveys to allow the extension of these uranium ore sorting techniques to other minerals.

---

* Senior Scientific Officer and ** Technicians, Mineral Physics Section, Mineral Sciences Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

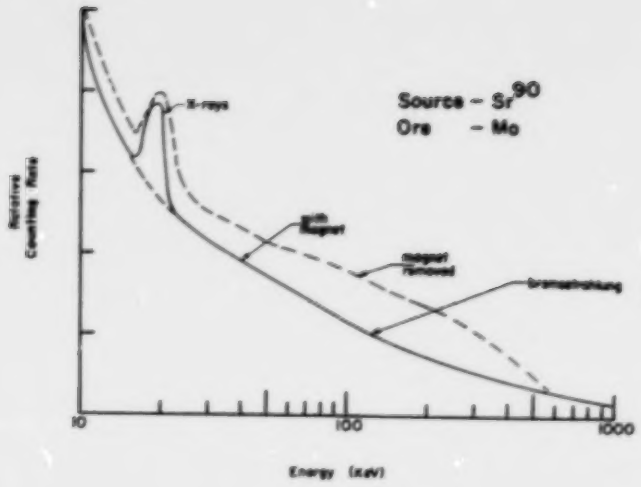
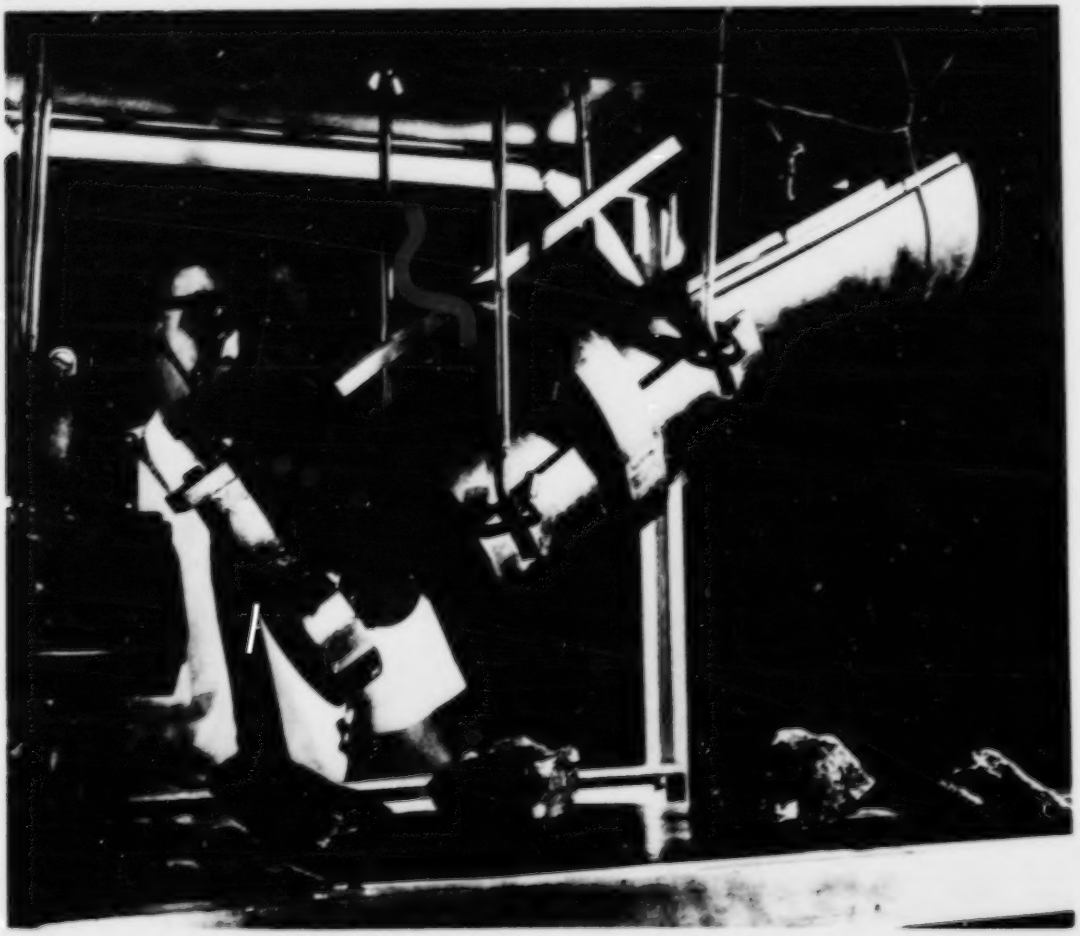


Figure 1 - Pulse height spectrum of molybendum ore excited by Sr^{90} beta rays.

Figure 2 - Detector and source assembly for Electronic Ore Sorter.



This system operates on ore sizes from 2 to 10 inches. The rejection of the waste material before much effort has been spent in processing means that for a given grinding capacity and reagent quantity, a greater output of final product will be obtained.

PRINCIPLES OF OPERATION

This system detects the mineral by exciting characteristic X-rays of the element present, with beta radiation (electrons) from a strontium-90 source. These electrons interact with the ore in a variety of ways; they may be elastically or inelastically scattered, they may cause Bremsstrahlung, or they may excite X-rays characteristic of the elements present in the sample. These various contributions are shown in the pulse height (energy) spectrum, Figure 1. A photograph of the detecting system is shown in Figure 2, and a line drawing of this system is shown in Figure 3.

The composite spectrum is collimated by collimator A and passes through permanent magnet M. This deflects any charged particles (electrons) in the beam. The electromagnetic radiation passes through collimator B into the proportional counter, and the resulting X-ray spectrum is analyzed using a single-channel analyser. When X-rays of an energy corresponding to the desired element are detected, they are amassed in a conventional counting system. If this total exceeds a certain preset value, the piece is routed for further processing. If the characteristic X-rays of the element searched for are not found, the rock is rotated and another face is scanned. Three such passes are made, and if at the end of these passes the desired

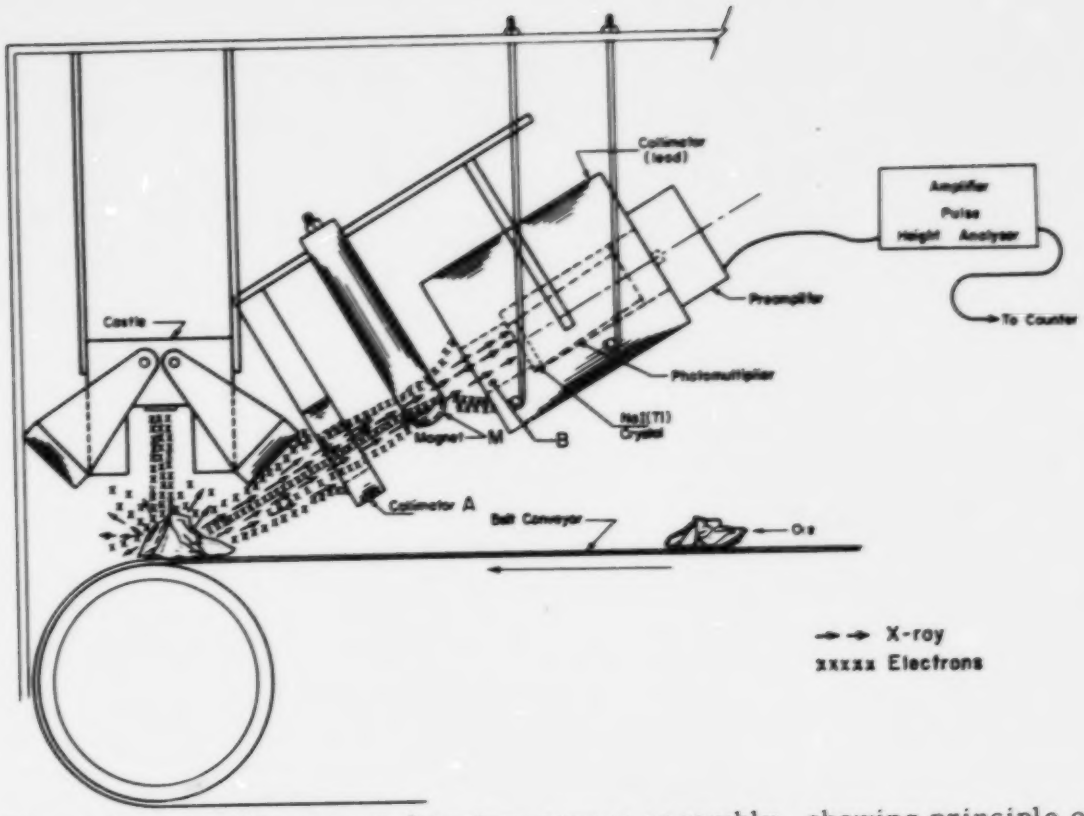


Figure 3 - Line drawing at detector-source assembly, showing principle of operation. The fail-safe castle has been turned 90° for illustration purposes.

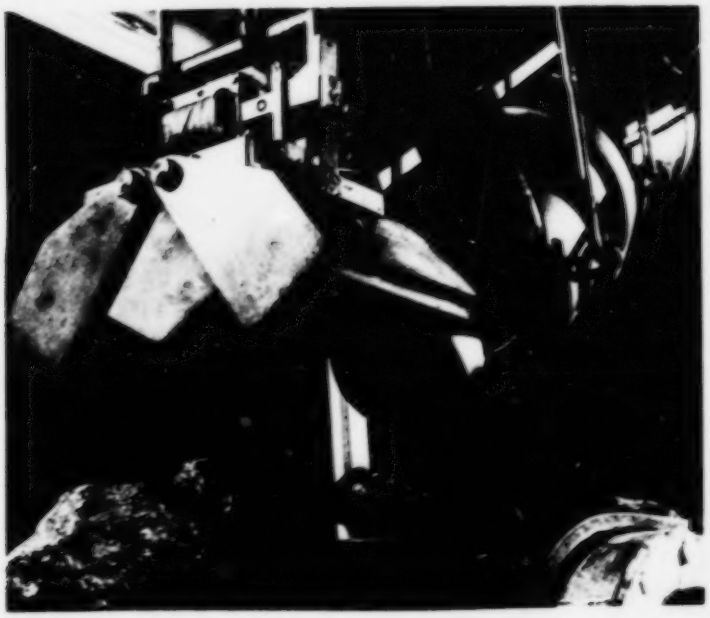


Figure 4 - Photograph of source holder. Note solenoids for closing door automatically.

element has not been detected, the rock is rejected as waste. This article will primarily concern itself with the following features of the system: the fail-safe castle for housing the radioactive strontium-90 source and the electronic detector system.

FAIL-SAFE CASTLE

The radiation used for this system comes from a 200 millicurie (7.4×10^9 disintegrations per second) strontium-90 source. This radioactivity is dangerous, and extensive precautions have been taken to ensure that the radioactivity is confined, especially in emergency situations. A picture of the fail-safe castle is shown in Figure 4. The strontium-90 source consists of a ceramic-like material, strontium titanate, which is embedded in a silver matrix. This was supplied by the Radiochemical Centre of Amersham, England.

The source is retained behind a screen which is secured in the lead castle. Two doors of the castle are held open by bars as shown in the figure. The doors automatically close under gravity when the bars are raised by means of the 2 solenoids shown in the diagram. The bars then drop down and lock the doors securely shut.

Figure 5 is a circuit diagram of the control unit of this castle. The solenoid driver is a fail-safe system. In the event of a power failure or the failure of the fused fire link in the power line, the relay shorts the capacitors across the solenoids thus closing the doors. The voltage applied to the solenoids is a pulse of amplitude twice their normal operating voltage

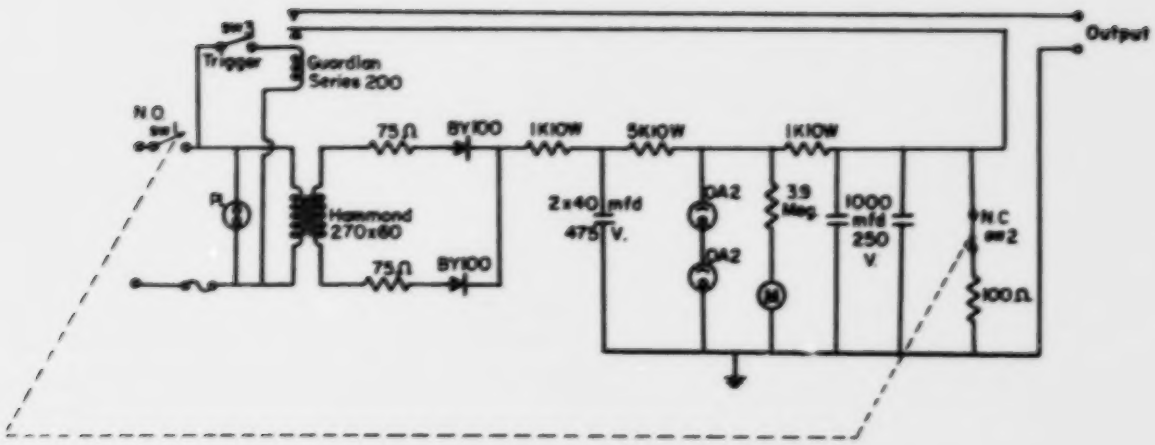


Figure 5 - Circuit diagram of castle solenoid driver unit.

and thus an extremely high mechanical impulse is generated. This system has been found to work reliably in many tests. The radiation close to the castle with the doors closed is 1/100 of the tolerance dose, and is barely detectable using conventional monitors at a distance of 3 feet from the castle.

THE DETECTION SYSTEM

The detection system uses a proportional counter, which has the advantage of a relatively good resolution at low energies, a single-channel pulse-height analyzer, and a count-rate meter. The single-channel analyzer is set so that it accepts the appropriate X-ray energy. When the input counting rate in the energy window exceeds a certain value, the trip meter actuates a solenoid valve which transfers the material for further processing. As long as the counting rate does not exceed this predetermined level, the material is rejected. A lower level trip point is used to ring an alarm if the castle should close.

APPLICATIONS AND USES

In order for this system to have economic advantage, the material to be sorted must possess certain characteristics. The desired mineral should occur in localized quantities interspersed in the rock. The pieces of ore to be sorted should have a high surface concentration of the desired mineral, since the X-rays do not penetrate more than a few millimetres below the surface. This type of ore sorter therefore is clearly

not useful for a disseminated ore. There is a practical range of concentration of ore where this system becomes useful since, for a high-grade ore, it is more economical to process the entire output of the mining operation. The usefulness of this sorter has been demonstrated for ores of arsenic, selenium, molybdenum, niobium, caesium, tungsten and lead. Ores containing elements of atomic number less than 36 cannot easily be detected. This lower limit is set because of the absorption of the characteristic X-rays by the air between the sample and the detector. Detection of the heavier weight elements is extremely easy, while for those near the air absorption limit the operation is somewhat more involved.

Speed of operation of the system is such that each piece requires approximately 1/10th of a second to pass under the detector. To increase the capacity of this system a number of sorters may be operated in parallel. It is hoped that the sorting of ores of the heavy elements proves of value to the mining industry and further enhances the productivity for mines with low grade ores.